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B71 11016

date: November 12, 1971

to: Distribution

from: C. Bendersky

subject: AF/OOS 25,000 lb Thrust LO_2/LH_2 Engine Study Reviews at Rocketdyne, Aerojet and Pratt and Whitney, September 13, 14, and 16, 1971 - Case 237

ABSTRACT

The results of three separate point design studies on a 25,000 lb thrust H_2/O_2 high performance engine for use in the Air Force Orbit-to Orbit Shuttle are described. The engine cycle, performance, weight, and preliminary cost estimates are included.

(NASA-CR-125975) AF/OOS 25,000LB THRUST LO2/LH2 ENGINE STUDY REVIEWS AT ROCKETDYNE, AEROJET AND PRATT AND WHITNEY, 13, 14, AND 16 SEPTEMBER 1971 (Bellcomm, Inc.) 7 p

N79-72562

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MEMORANDUM FOR FILE

1.0 INTRODUCTION

Previous memoranda[1,2] described the Air Force sponsored studies on H_2/O_2 Orbit-to-Orbit Shuttles (OOS), a propulsion module in many ways similar to the NASA Space Tug concept. It was reported that the Air Force Space and Missiles Systems Organization (SAMSO) had both the North American Rockwell Space Division (NAR/SD) and the McDonnell Douglas Astronautics under contract to perform vehicle systems studies. In direct support of these studies, the Air Force Rocket Propulsion Laboratory (RPL) has the Rocketdyne Division of North American Rockwell (RKD), the Aerojet Liquid Rocket Company (ALRC) and the Pratt and Whitney Aircraft Company (P&W) under contract to define the characteristics of the high performance H_2/O_2 main propulsion for the OOS. Initially, the contracts were worth approximately $500,000 each and required derivation of parametric data for candidate bell nozzle rocket engine cycles over a 8000-to-50,000 lb thrust range and an in-depth point design at the 25,000 lb thrust level of the best candidate cycle as determined by the results of the two SAMSO vehicle studies. As a result of the vehicle trade studies, RPL chose variations of a high pressure topping cycle for detail design.

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[1] C. Bendersky, "AF/OOS Propulsion Reviews, Los Angeles, California, June 23-24, 1971", Memorandum for File B71 07040, Case 237, July 28, 1971.

[2] C. Bendersky, "Main Propulsion Selections; Pre Phase A NASA Space Tug Studies", Memorandum for File B71 05017, Case 105-4, May 18, 1971.

NASA has become interested in a high performance H_2/O_2 engine having approximately 10,000 lb of thrust. This size engine, used singly or clustered in a multi-engine configuration, has potential for use in NASA Tug, OSSA Versatile Upper Stage (VUS) or Space Shuttle on-orbit maneuvering applications. As a result, OMSF provided \$50,000 to each contractor to perform a point design at 10,000 lb thrust to the same depth as was performed in the RPL 25,000 lb thrust engine designs. This added task is being administered by RPL.

The characteristics of the three 25,000 lb engine point design were reviewed and the 10,000 lb thrust engine tasks were initiated during meetings held on September 13 at RKD Canoga Park, California, on September 14 at ALRC Sacramento, California and on September 16 at P&W West Palm Beach, Florida. This memorandum describes the presentations.

2.0 DISCUSSION

2.1 25,000 lb Thrust Engine Configurations

The 25,000 lb vacuum thrust engine concepts selected for detail design were all variations of the high pressure staged combustion cycle. The engine is required to operate at a mixture ratio (MR) of 6 ± 0.5, over a 5:1 throttling range and is length constrained. Reusable engine lifetimes of 10 hours, 60 starts and 300 thermal cycles were specified.

The RKD design is based on the features of the main propulsion engine design which won the recent Space Shuttle competition. The configuration employs a separate or individual preburner for powering each of the two turbopumps. Separate boost pumps driven by heated H_2 from the nozzle skirt are provided to meet net positive suction pressure (NPSP) specifications. The main combustion chamber and nozzle are regeneratively cooled. The main chamber is made of milled NARLOY-Z channels, and the nozzle is made of tapered nickel tubing. The main injector is similar to that of the J-2, and it is provided with acoustic absorbers to enhance the inherent combustion stability of the design. Performance is estimated to be 473.7 seconds of I_{sp} at a chamber pressure (Pc) of 2200 psia, MR = 6.0 and an expansion ratio (ε) of 350:1. The engine dry weight estimate was 393 lb.

The ALRC configuration has a single preburner to drive both turbopumps. Low speed inducers are built into the turbopump and so separate boost pumps are not needed. The LO_2 pump is a two stage split flow design in which the first stage pumps about 80% of the flow to the main combustion chamber and the second stage pumps approximately 20% of the LO_2 flow rate to the higher pressure level required by the preburner. The thrust chamber is similar to the RKD concept except that ZrCu is used in the milled slot chamber and Armco 22-13-5 in the tubular nozzle. Both pre and main combustor injectors are designed to provide supercritical temperature (essentially gaseous) O_2 at the combustion plane. The combustion processes are therefore gas/gas and easier to control and throttle efficiently. Fabrication of these injectors, however, requires advanced technology development. The preburner is provided with an acoustic resonator, integral with the preburner chamber, to provide a combustion stability margin.

The ALRC performance is estimated to be 471 seconds of I_{sp} at a nominal MR = 6, Pc = 1800 psia and $\varepsilon = 290$. The engine system weight was estimated to be 459 lb.

The P&W version of the staged combustion cycle is called an "augmented expander cycle". In reality the flow schematic is similar to that of ALRC. The configuration has a single preburner driving dual turbopumps. Separate boost pumps, gear driven from the LO_2 turbine, provide required NPSP. The LO_2 pump is a two stage split flow type similar to the ALRC design. The thrust chamber has three sections. The chamber is milled-slot AMSIRC and electro formed nickel, the central portion is tubular Inconel 625, and the downstream portion is a dump cooled Inconel 625 corrugated nozzle. The chamber and tubular nozzle are regeneratively cooled and the heated hydrogen is fed directly to the preburner or augmentor as it is called by P&W. The main and preburner designs are derived from the experience gained in the A/F XLR129P-1 program.

The P&W performance is estimated to be 465 seconds of I_{sp} at a nominal MR = 6, Pc = 1900 and $\varepsilon = 290$. The total dry engine weight was estimated to be 425 lb. It was stated that a light-weight redesign study resulted in a reduced weight estimate of 375.2 lb.

2.2 Cost Estimates

The study requirements called for costing analysis. RKD and ACRC provided preliminary cost estimates based on a nine year research and development program. The first five years is an advanced development program (ADP) having the objective of fabricating and testing a demonstrator engine defined as flight type but not flight weight. P&W provided a cost estimate for a conventional development program. A summary of the preliminary results are presented below.

	Demonstrator Program	Development Engine	First Production Unit
RKD	$32,000,000	$117,000,000	$887,000
ALRC	$18,000,000	$44,700,000	$831,000
P&W	--	$124,000,000	Not Avail.

It was generally agreed that early commitment to a full development program omitting the ADP would not increase the total estimated cost of the program.

2.3 10,000 lb Thrust Engine Task

There were general discussions with each contractor to see if any significant changes in study ground rules would be desired at the lower thrust engine size. None evolved.

Each of the contractors stated that the major anticipated design problems would be in the turbomachinery area. Clearances and tolerances become quite small with such a small engine and its fabrication might not be adaptable to conventional production tooling. Development costs of the smaller engine were expected to be about the same as that for the 25,000 lb thrust engine. This task will be completed by the end of 1971.

3.0 REMARKS

Of the three designs, the ALRC version requires the most advanced technology; the RKD and P&W are comparative, with the P&W approach slightly more conservative.

The performance estimates are consistent with state of the art trends of Pc and ϵ. The lower P&W performance is due to both a lower assumed combustion efficiency and losses caused by dump cooling the nozzle skirt. The engine weights are not comparable primarily because of the contractor differences of interpretations as to what components the engine manufacturer delivers. Nevertheless, the P&W concept would be expected to be slightly lighter because of the dump cooled skirt, the split flow LO_2 pump and the gear driven boost pumps. The P&W lightweight design concept weighing 375 lb appears slightly optimistic.

The ALRC design, which requires the most advanced technology, was priced at approximately 30 percent of that of RKD and P&W. The maxim that the less known about a system the less it is believed to cost is again brought to mind. It would appear that both the RKD and P&W designs are competitive based on the depth of data presented.

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Attachments

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